MILLIKAN OIL DROP EXPERIMENT

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1 Introduction

The Millikan oil drop experiment entailed observing tiny electrically charged droplets of oil located between two parallel metal surfaces, forming the plates of a capacitor. The plates were oriented horizontally, with one plate above the other. A mist of atomized oil drops was introduced through a small hole in the top plate and was ionized by x-rays, making them negatively charged. First, with zero applied electric field, the velocity of a falling droplet was measured. At terminal velocity, the drag force equals the gravitational force. As both forces depend on the radius in different ways, the radius of the droplet, and therefore the mass and gravitational force, could be determined (using the known density of the oil). Next, a voltage inducing an electric field was applied between the

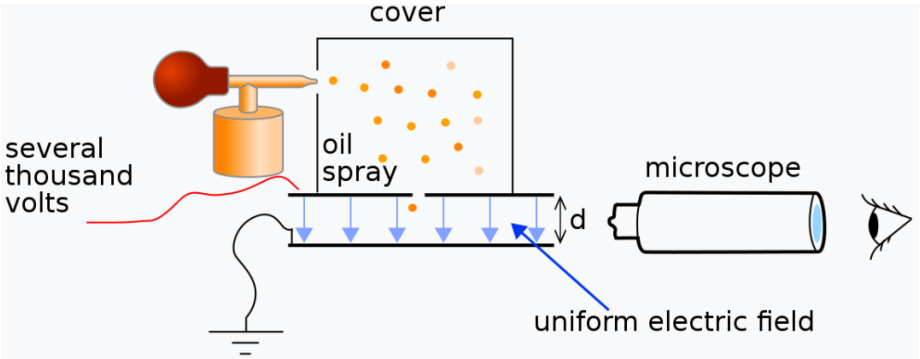


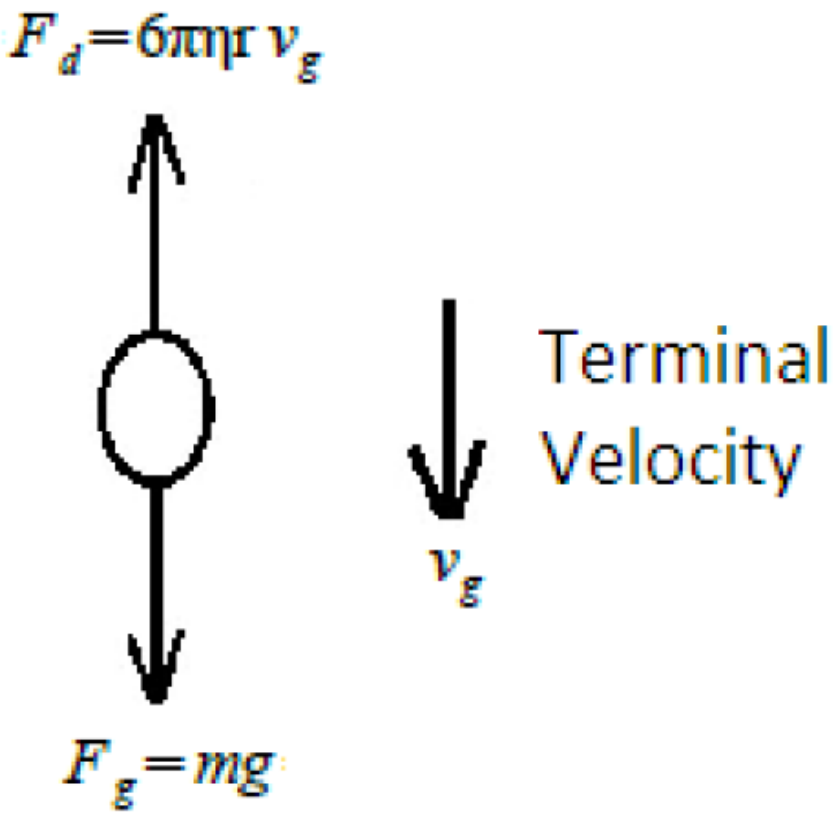
Figure 1: Simplified scheme of Millikan's oil drop experiment

plates and adjusted until the drops were suspended in mechanical equilibrium, indicating that the electrical force and the gravitational force were in balance. Using the known electric field, Millikan and Fletcher could determine the charge on the oil droplet. By repeating the experiment for many droplets, they confirmed that the charges were all small integer multiples of a certain base value, which was found to be $1.5924(17) \times 10^{-19}$ C, about 0.6% difference from the currently accepted value of $1.602176634 \times 10^{-19}$ C. They proposed that this was the magnitude of the negative charge of a single electron.

2 Theory

2.1 Measuring Radius Of Oil Drop

Consider a spherical oil droplet of radius *'r'* and density *'ρ'* falling under the gravitational force. This droplet in air is acted upon by a constant force and soon reaches a terminal velocity given by Stoke's law, $F_d = 6\pi\eta r v_g$, where η' is the coefficient of viscosity of air and v_g is the terminal velocity during the fall. The gravitational and buoyancy forces acting on the droplet are balanced by F_d.



In the absence of electric field, the velocity of falling drops quickly increases to the constant velocity (called as 'terminal velocity'). This happen when the viscous force $F_d = 6\pi\eta r v_g$ become equal to the gravitational force $F_g = mg$.

$$F_g = F_d$$

$$mg = 6\pi\eta r v_g$$

$$V\rho g = 6\pi\eta r v_g \qquad \{m = volume X density\}$$

$$\frac{4}{3}\pi r^3 \rho g = 6\pi\eta r v_g$$

$$r = 3\sqrt{\frac{\eta v_g}{2\rho g}}$$

η=Viscosity of fluid (i.e air)
r =Radius of droplet
ρ=Density of liquid.

2.2 Method to find charge 'Q' for each drop

We measure Voltage V needed to keep the droplet stationary to find Q for each drop .

$$mg = qE$$

$$mg = \frac{4}{3}\pi r^3 \rho g = 6\pi\eta r v_g$$

$$E = \frac{V}{d}$$

$$q = \frac{6\pi\eta v_g r d}{V} = \frac{6\pi\eta v_g d}{V}\sqrt{\frac{9\eta v_g}{2\rho g}}$$

3 Observations

- Distance between capacitor plates = 5 $\times$ 10^{-3} m
- Droplet motion distance = 1 x 10^{-3} m
- Coefficient of viscosity = 1.83 x10^{-5} kg/ms
- Density of oil = 981 kg m^{-3}
- falling speed v_g = 1 x 10^{-3}/time
- r=$\sqrt{\frac{9\eta v_g}{2\rho g}}$
- q=$\frac{6\pi\eta v_g r d}{V}$
- number of charges = roundup value of $\frac{q}{e}$
- e is the minimum value of q obtained

Suspension Voltage	Distance	Freefall time	Terminal Velocity	Charge	n	Elemental Charge	Relative error(%)
140	1	11	9.09E-05	9.88E-19	6	1.65E-19	2.948063299
130	1	10	0.0001	1.23E-18	8	1.53E-19	4.070284737
240	1	19	5.26E-05	2.54E-19	2	1.27E-19	20.63758848
200	1	3.5	0.0002857142857	3.85E-18	25	1.54E-19	3.636087669
160	1	8.56	0.0001168224299	1.26E-18	8	1.57E-19	1.583961847
220	1.5	42.29	3.55E-05	1.53E-19	1	1.53E-19	4.204705975
200	1	30.87	3.24E-05	1.47E-19	1	1.47E-19	8.028863148
180	1	12.47	8.02E-05	6.37E-19	4	1.59E-19	0.4928430494
120	1.5	25.28	5.93E-05	6.08E-19	4	1.52E-19	5.001545161
240	1.5	19.31	7.77E-05	4.55E-19	3	1.52E-19	5.132495583
160	1.5	30.5	4.92E-05	3.44E-19	2	1.72E-19	7.528514464
240	1.5	38.57	3.89E-05	1.61E-19	1	1.61E-19	0.8179084214
10	1.5	63.94	2.35E-05	1.81E-18	12	1.51E-19	5.532333151
40	1.5	60.28	2.49E-05	4.95E-19	3	1.65E-19	3.200611769
100	1.5	60.69	2.47E-05	1.96E-19	1	1.96E-19	22.58792023
60	1.5	41.38	3.62E-05	5.81E-19	4	1.45E-19	9.275117986
60	1.5	31.56	4.75E-05	8.72E-19	6	1.45E-19	9.193823264
80	1.5	75.87	1.98E-05	1.75E-19	1	1.75E-19	9.629711241
100	1.5	33.9	4.42E-05	4.70E-19	3	1.57E-19	2.118057099

4 Result:

The observed average value of Quanta of charge is 1.57×10^{-19} **C**
The Relative error is 6.611%

5 Precautions

- The drop selected for observations should be kept moving up (by switching on the power supply) and down (by switching off the power supply) so that at least three sets are taken for vg and ve. The potential V is being kept constant for the whole set of observations.
- The timing of the droplets for calculations of vg and ve should be done with an accurate stop watch reading to 1/10th of a second.
- Many drops should be examined under different electric fields.
- If a lateral displacement of drop occurs, then this drop must be rejected as it is due to the collisions.
- Whenever, the speed of the drop suddenly changes, it may have acquired more charge or mass . When this happens the drop cannot be used to repeat its earlier observations, but may be used as a fresh drop for a fresh set of observation.